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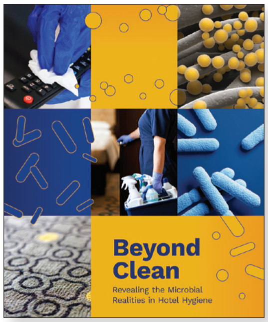

Enhanced Hotel Room Cleaning: Environmental Microbiological Sampling Investigation in a Midscale Hotel Property

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Abstract **The purpose of our study was to illustrate the efficacy of an enhanced cleaning process during a pandemic by quantifying generic and pathogenic microorganisms before and after cleaning in hotel rooms. The objectives of our study were to: 1) sample high-touch surfaces before and after the rooms were cleaned and 2) swab high-touch surfaces using an adenosine triphosphate (ATP) meter before and after the rooms were cleaned. Overall, 10 rooms and 37 surfaces per room were sampled before and after cleaning. The results showed that several areas of the room had a higher *Staphylococcus aureus*, aerobic plate, and *E.coli*/coliform counts after cleaning, suggesting that contaminated towels were being used to clean various surfaces in the rooms. In addition, we found no correlation between microbial counts and ATP meter readings. These results show that a more effective method needs to be assessed for practitioners to effectively quantify environmental safety in hotel rooms.**

Keywords: pandemic, lodging industry, cleaning, microbiology, environment, housekeeping, public health, hotel

Introduction

Historically, hotel rooms have been linked with major bacterial and viral outbreaks, including outbreaks of Legionnaires' disease in 2015 (Ahmed et al., 2019) and 2017 (Yackley et al., 2018), Norwalk-like virus in 1996 (Cheesbrough et al., 2000) and 2012 (Raj et al., 2017), severe acute respiratory syndrome (SARS) in 2003 (Bell, 2004), and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in 2021 (Leong et al., 2021). At the beginning of May 2023, the World Health Organization (WHO, 2025) declared that the global pandemic caused by COVID-19 was considered well-established and ongoing and no longer classified as a public health emergency of international concern. As such, federal, state, and local officials have stopped enforcing pandemic safety measures, including the requirement of face masks and social or physical distancing.

Several studies, however, have reported that consumers still value and might even have higher expectations for cleaning and safety protocols that have been implemented by hospitality operations in response to the pandemic (Li et al., 2021; Qi & Chen, 2023; Sawang et al., 2023). Further, Jiang and Wen (2020) emphasize the need to integrate hotel hygiene and cleanliness into marketing and management strategies and consider how guests perceive the cleanliness of specific hotel surfaces. They also recommend further research into the evolving relationship between the hospitality and healthcare sectors.

Many hotels have placed an emphasis on cleaning practices and have incorporated images related to cleanliness and safety messaging into their marketing strategies (Herédia-Colaço & Rodrigues, 2021; Jiménez-Barreto et al., 2021; Peco-Torres et al., 2021). To restore and maintain consumer confidence in safe travel, several leading hotel brands have partnered with sanitation companies to implement enhanced cleaning programs that target high-touch surfaces in lodging operations (Ecolab, 2021; Hilton, 2021; IHG, 2021; Marriott, 2021; Reckitt, 2021; Wyndham Hotels, 2021).

Although this enhanced cleaning is a step in the right direction, hotels still rely only on visual assessment as a measure of cleanliness and do not take into consideration the bacteria or organic matter that could be present on surfaces found in the guest rooms (Almanza et al., 2015). Moreover, studies have highlighted the ineffectiveness of relying on visual assessment as an indicator of environmental and surface cleanliness (Almanza et al., 2015; Inkinen et al., 2020; Shimoda et al., 2015; Xu, Weese, et al., 2015).

Studies that have identified and quantified biological contaminants (e.g., bacteria) on high-touch surfaces have relied on microbiological techniques such as aerobic plate counts (APCs) and coliform counts to assess the cleanliness of surfaces in various environments. For example, APCs are used to assess levels of generic bacteria in a given sample (Maturin & Peeler, 2021), which is why this technique is commonly used as an indicator of environmental cleanliness. Additionally, *E. coli* and coliforms are commonly used as indicators of fecal contamination in the environment (Feng et al., 2020). Although not all strains of *E. coli* are inherently pathogenic, they can act as opportunistic pathogens that present potential risks for immunocompromised hotel guests who come in contact with contaminated surfaces (Feng et al., 2020).

Another environmental microorganism of note is *Staphylococcus aureus*, which is a potential concern in the hotel room setting because the pathogen is naturally produced by the human body, has a high transmission rate, can survive on a variety of surfaces for months at a time, and is highly resistant to desiccation (Lutz et al., 2013). Further, *S. aureus* is an opportunistic pathogen and a major cause of nosocomial infections (Otto, 2009), meaning that if the skin or mucous membranes (which serve as barriers against infection) are breached, *S. aureus* might gain access to underlying tissues or the bloodstream and cause infection (Minnesota Department of Health, 2010). Due to the nature of this pathogen and its ability to persist on surfaces, a major risk for travelers could be present if they have open wounds or if they belong to an immunosuppressed population.

To date, we know of no research that has evaluated the microbiological efficacy of the enhanced cleaning procedures implemented in response to the COVID-19 pandemic since 2020. General cleaning practices in hotel rooms follow common cleaning practices such as removing linens, making the bed with fresh linens, clearing the trash, and cleaning the bathroom (Kline et al., 2014).

In response to the COVID-19 pandemic, lodging operators have placed a much greater emphasis on wiping and disinfecting surfaces to enhance consumer perceptions of hotel and lodging safety. A common method used in lodging and food service establishments to assess surface cleanliness is using an adenosine triphosphate (ATP) meter. ATP meters provide a practical means of assessing surface cleanliness for hospitality professionals; the devices are user-friendly, require minimal training, and offer immediate results in relative light units (RLUs). These meters, however, measure ATP that is present in all types of organic material—including food, soil, and bacteria—and thus are unable to distinguish the difference between microbial and nonmicrobial contamination (Bellamy, 2012).

Moreover, studies have shown mixed results as to the true reliability of ATP meters as indicators of surface cleanliness, particularly in correlation with traditional microbial plate count methods (Deshpande et al., 2020; Omidbakhsh et al., 2014; Snyder et al., 2013). This gap in knowledge presents a health and safety risk for consumers and lodging operators, as travelers have been found to spread diseases caused by bacterial and viral microorganisms such as *E. coli* O157:H7 (King et al., 2020), *Staphylococcus* spp. (Xu, Mkrtchyan, et al., 2015), *Streptococcus* (Weiser et al., 2018), hepatitis (Centers for Disease Control and Prevention [CDC], 2019), rhinovirus (Winther et al., 2011), rotavirus (Kribs-Zaleta et al., 2011), and influenza (CDC, 2024a) through indirect contact via high-touch fomites, which are objects capable of transmitting infection. A key output of these studies showed the importance of creating and maintaining effective cleaning programs designed to enhance not only guest perceptions of the lodging property but also guest safety by reducing potentially pathogenic microorganisms to safe levels.

To address this gap, microbiological sampling of high-touch surfaces in addition to the use of an ATP meter can offer a more robust assessment of enhanced cleaning practices (ECPs) by identifying microorganisms commonly used as indicators of environmental cleanliness in addition to the organic residue detected by the ATP meter. According to the Centers for Disease Control and Prevention (CDC, 2024b), microbiological sampling of the environment is an effective approach for quality assurance purposes to evaluate the effects of a change in infection control practices or to ensure that systems perform according to specifications and expected outcomes. Although routine microbiological sampling of hotel rooms might not be practical for lodging operations due to costs and the time required for laboratory testing (Park et al., 2019), having a microbiologic comparator is appropriate when assessing changes in infection control practices (Snyder et al., 2013), especially considering that the goal of ECPs implemented during a pandemic is to ensure guest safety by enhancing hygiene and infection prevention practices.

Therefore, the objectives of our study were 2-fold:

1. To assess current ECPs specific to 37 high-touch surfaces found in hotel rooms by collecting 740 environmental samples and 740 ATP meter readings in 10 hotel rooms to quantify the number of microorganisms and organic matter, respectively, present on high-touch surfaces in hotel rooms.
2. To analyze the data collected to determine if there were statistically significant differences in the number of logs for the microorganisms detected during microbiological sampling and organic matter detected with the ATP meter before and after the rooms were cleaned.

Methods

Study Setting and Surfaces

A microbial sampling of high-touch surfaces was conducted in 10 hotel guest rooms. These rooms are representative of standard guest rooms in midscale hotel properties in the U.S. A total of 37 surfaces were sampled in our study and divided into 3 areas of use:

1. Guest traffic area, which included the doorknobs inside of the bedroom, closet door handles, drapery pull handles, tabletop, table handles, dresser handles, climate control panels, iron handles, coffee makers, safety latches, peepholes, trash cans, entry carpet, and the light switch for the bedroom.
2. Bed area, which included the lamp switches, telephone handset, telephone keypad, remote control keypad, clock (which doubled as a phone dock), pillowcases, top of the nightstand, and nightstand handles.
3. Bathroom area, which included the toilet handles, toilet seats, amenity trays, bathroom sink, bathroom faucet handles, bathroom floor, shower floor, toilet paper holder, bathroom light switch, doorknob on the inside of the bathroom, doorknob on the outside of the bathroom, toilet bowl, hair dryer, vanity surface, and the shower handle.

The guest traffic area in our study is defined as the area where the guest is likely to interact with high-touch surfaces while moving around the room during their stay. The bed area focuses on high-touch surfaces that the guest is likely to interact with at arm's length from the bed. The bathroom area centers around high-touch surfaces that typically are found in bathrooms of midscale lodging properties.

To determine the list of high-touch surfaces, publicly available information was gathered from websites of leading hotel brands (Hilton, 2021; IHG, 2021; Marriott, 2021; Wyndham Hotels, 2021) that have implemented ECPs and the cleaning companies they have partnered with (Ecolab, 2021; Reckitt, 2021) and information gathered from health organizations (CDC, 2024a; WHO, 2021) that have identified high-touch surfaces in various settings. Additionally, the American Automobile Association (AAA, 2021) has implemented the Inspected Clean Program that is used when evaluating their Diamond Rating of hotels and specifies the surfaces that have been included in this list.

Before the start of the sample collection, each standard guest room was visually inspected to confirm all of the established surfaces were present in the room and to identify where the sampling would occur. We determined that all 37 surfaces were present in the room. Many of the surfaces in the hotel room had two of the same surfaces (e.g., two lamps, two nightstands, two closet handles), for which one was designated for the ATP meter measurement and the other was used to collect microbial samples. For surfaces that had only one surface to sample, the surface area was large enough that it could be easily divided to allow for a 5 × 5 cm^2 sampling area for both the ATP meter and the microbial samples. Environmental sampling took place at the beginning of July 2021 and continued until the end of January 2022. A total of 740 microbial samples and 740 ATP meter readings were collected from high-touch surfaces in hotel rooms. Additionally, a hygrometer was taken into the hotel rooms and recorded an average room temperature of 68.8 °F and an average relative humidity of 55%.

Laboratory Preparation

Aluminum foil was cut into 5 × 5 cm^2 templates to control for the surface area that was swabbed during the sample collection process. Test tubes (37 for each surface) containing 9 mL of 1% peptone water (PW; Difco) were prepared before each sampling event to collect samples from high-touch surfaces before and after cleaning for each room sampled in our study. To control for any residual sanitizers that could be present during the sample collection, 0.9 ml (10%) of Dey-Engley Neutralizing Broth was added to each sample collection tube that was used to collect samples after the room was cleaned. All materials were sterilized by autoclave at 15 lb (7 kg) of pressure (121 °C) for 15 min.

Sample Collection

For the bacterial profile, each surface was swabbed aseptically before the room was cleaned using sterile cotton-tipped plastic swabs moistened with PW in a 5 × 5 cm^2 area on each surface. Sterile 5 × 5 cm^2 aluminum foil templates were used to control for variability in surface area sampling sizes. After the sampling of each surface, the untouched ends of the cotton-tipped plastic swabs were broken off to prevent possible contamination and placed in sterile test tubes containing 9 ml of PW. Samples were then placed in a portable cooler with ice (<10 °C) and transferred to a microbiology laboratory for analysis.

Following the hotel room cleaning, sampling was conducted again 1 hr after the room was cleaned to allow an adequate amount of time for cleaners and surface sanitizers to air-dry. As an added control, a neutralizing agent was added to the sample collection tubes to negate the effect of any residual sanitizers on sampled surfaces.

For sampling conducted with the ATP meter, surfaces were swabbed to determine if the presence of ATP was detected. Sterile templates were placed on surfaces in the room and swabbed using the Hygiena UltraSnap Surface Swabs per manufacturer instructions. Results from each sample were generated in real time within 15 s and recorded for each surface before and after cleaning. The ATP meter was recalibrated per manufacturer instructions prior to each sampling event. A total of 10 rooms were sampled over 6 months from July 2021 to January 2022.

Microbiological and Statistical Analysis

After the surface samples were collected, they were transported to a Biosafety Level 2 laboratory for microbiological analysis. Next, 10-fold serial dilutions were made by passing 1 ml of each collected sample into a test tube containing 9 ml of PW. Then 1 ml from each dilution (3 dilutions) was placed onto the appropriate 3M Petrifilm Plates to quantify APCs, *E. coli*/coliforms, and *S. aureus* for each sample and the plates were incubated at 37 °C for 24–48 hr. The total viable count was determined based on the distinct color of the microorganisms on each of the plates. Microbial colonies were manually counted using a Quebec colony counter to quantify the presence of aerobic bacterial contamination, generic *E. coli* and coliforms, and *S. aureus* as indicators of microbial contamination for each surface.

Bacterial counts were converted by using the log formula in Microsoft Excel before the statistical analysis. The data from the 10 rooms were then transferred into IBM SPSS Statistics version 28 and the mean log CFU/cm^2 and RLU/cm^2 were compared using a paired samples *t*-test to determine if there were statistically significant differences ($p < .05$) based on the microorganism and area of the hotel room.

Results

Sample Analysis Before and After Cleaning

The 37 sampled high-touch surfaces were divided into the guest traffic area, bed area, and bathroom area; surfaces were further grouped by the log CFU/cm^2 for APCs, *E. coli*/coliform counts, *S. aureus*, and RLU/cm^2 from the ATP meter readings for analysis. A paired samples *t*-test (95% confidence intervals) was conducted to determine if there were statistically significant differences in the samples taken before and after the hotel rooms were cleaned.

In general, *S. aureus* counts decreased in each of the three areas on all high-touch surfaces sampled in the hotel room. Over the course of our study, *E. coli* was not detected in any of the guest rooms. Coliform counts, however, increased in all three of the sampled areas on all high-touch surfaces, except for the closet handle, drapery pull handle, and shower floor. For the APCs, a majority of the high-touch surfaces included in the guest traffic area increased after the room was cleaned, whereas all surfaces in the bed area and bathroom area decreased except for the nightstand handle and hair dryer. Lastly, the ATP meter results found that RLUs detected decreased after the room was cleaned for all high-touch surfaces, with the exception of the carpet, telephone dial pad, doorknob inside the bathroom, and hair dryer. The following sections discuss the results of the paired samples *t*-test for the microbial and ATP data collected.

Guest Traffic Area

The guest traffic area consisted of high-touch surfaces the guest was likely to interact with in the hotel room that were farther than an arm's reach away from the bed area and not in the bathroom. The results of the paired samples *t*-test concluded that for total viable APCs, the log CFU/cm^2 before cleaning (M = 1.14, SD = 0.57) did not significantly decrease after the room was cleaned (M = 1.11, SD = 0.37, $t(13)$ = 0.348, p = .367). A majority of the surfaces included in the guest traffic area increased in the number of logs detected after the room was cleaned, except for the tabletop, dresser handle, coffee maker, and entry carpet. The only surface that demonstrated a statistically significant decrease in the logs detected for APCs was the entry carpet (M = 0.67, SD = 0.72, p = .008), which had an average of 2.68 log CFU/cm^2 before the room was cleaned and an average of 2.01 log CFU/cm^2 after the room was cleaned ($t(9)$ = 2.938, p = .008).

Overall, the log concentrations of the samples collected for coliforms before cleaning (M = 0.36, SD = 0.09) increased significantly after the room was cleaned (M = 0.55, SD = 0.11) in the guest traffic area ($t(13)$ = -4.656, $p < .001$). Although specific high-touch surfaces did not significantly increase, the doorknob inside the bedroom, tabletop, table drawer handle, dresser handle, climate control panel, iron, coffee maker, door safety latch, door peephole, trash can, entry carpet, and bedroom light switch all increased an average of 0.25 log CFU/cm^2 after the room was cleaned. Only the closet handle and drapery pull handle decreased an average of 0.14 log CFU/cm^2 and 0.10 log CFU/cm^2, respectively.

For *S. aureus*, the average log concentrations of the collected samples before cleaning (M = 1.08, SD = 0.48) significantly decreased after the room was cleaned (M = 0.63, SD = 0.38) for the guest traffic area ($t(13)$ = 7.900, $p < .001$). While all high-touch surfaces in the guest traffic area decreased an average of 0.36 log CFU/cm^2 for this specific microorganism, the surfaces that demonstrated a significant decrease in the number of logs detected after the room was cleaned were the doorknob inside of the bedroom (M = 0.43, SD = 0.61, p = .026); drapery pull handle (M = 0.21, SD = 0.34, p = .041); tabletop (M = 0.63, SD = 0.90, p = .027); climate control panel (M = 0.51, SD = 0.82, p = .041); iron handle (M = 0.60, SD = 0.82, p = .045); and coffee maker (M = 0.78, SD = 1.00, p = .018).

For the ATP meter data, the results from the paired samples *t*-test found that the detected RLUs on high-touch surfaces before cleaning (M = 91.8, SD = 112.77) significantly decreased after the room was cleaned (M = 49.76, SD = 51.22) in the guest traffic area ($t(13)$ = 2.471, p = .014). Specifically, the table drawer handle, climate control panel, door safety latch, and bedroom light switch significantly decreased in number of detected RLUs. All other surfaces in this area showed decreases in the organic matter detected, ranging from 3 to 231 RLUs, except for the entry carpet, which increased by 1 RLU on average. The results for the paired samples *t*-test in the guest traffic area are shown in Table 1.

Bed Area

Results from the statistical analysis for the bed area found that APCs before cleaning (M = 1.67, SD = 0.46) significantly decreased after the room was cleaned (M = 1.24, SD = 0.19, $t(7)$ = 2.452, p = .022). Specifically, the bedside lamp switch (p = .006); bedside clock/phone dock (M = 0.88, SD = 0.88, p = .032); and pillowcases (M = 0.74, SD = 1.05, p = .026) significantly decreased in the average number of log CFU/cm^2 for these high-touch surfaces. All other surfaces decreased an average of 0.39 log CFU/cm^2 after the room was cleaned except for the nightstand handle, which increased an average of 0.51 log CFU/cm^2 after cleaning.

For coliforms, the log concentrations before cleaning (M = 0.46, SD = 0.11) also significantly increased after the room was cleaned (M = 0.81, SD = 0.13, $t(7)$ = -8.925, $p < .001$). For this microorganism, microbial counts significantly increased on the phone dial pad (M = -0.44, SD = 0.74, p = .046) and TV remote control (M = -0.54, SD = 0.65, p = .013). All other surfaces that were tested for the presence of coliforms in the bed area increased an average of 0.33 log CFU/cm^2.

Contrary to the results for coliforms, microbial counts for *S. aureus* before cleaning (M = 1.44, SD = 0.37) significantly decreased after the bed area was cleaned (M = 0.89, SD = 0.13, $t(7)$ = 5.688, $p < .001$). Specifically, the high-touch surfaces that had significant log reductions for *S. aureus* in this area were the bedside clock/phone dock (M = 0.90, SD = 1.15, p = .017); pillowcases (M = 0.72, SD = 0.70, p = .005); and nightstand top (M = 0.87, SD = 1.20, p = .023). All other surfaces in this area had a mean log reduction of 0.31 log CFU/cm^2 after the room was cleaned.

For the ATP meter data, our results indicate that the average RLUs detected on high-touch surfaces in the bed area before cleaning (M = 159.03, SD = 129.68) significantly decreased after the room was cleaned (M = 66.26, SD = 42.70, $t(7)$ = 1.948, p = .046). Overall, high-touch surfaces were deemed cleaner according to the ATP meter readings; however, the surface of the phone dial pad increased an average of 7 RLU/cm^2. The only surface that had a significant decrease in the average RLU detected was the bedside clock/phone dock (M = 57.3, SD = 60.50, p = .008), whereas all other surfaces decreased an average of 116 RLU/cm^2. Results for the paired samples *t*-test for the bed area are shown in Table 2.

Bathroom Area

For the data collected from the bathroom area, results indicated that the APCs detected before cleaning (M = 1.88, SD = 0.70) significantly decreased after the bathroom was cleaned (M = 1.37, SD = 0.37, $t(14)$ = 3.878, $p < .001$). Specifically, the sink faucet handles (M = 0.87, SD = 1.22, p = .033); bathroom floor (M = 1.06, SD = 1.59, p = .032); shower floor (M = 1.48, SD = 0.87, $p < .001$); and vanity surface in front of the sink (M = 1.26, SD = 0.75, p = .002) all had significantly lower log CFU/cm^2 following the room cleaning. The hair dryer was the only high-touch surface in the bathroom that increased in APCs; it increased by an average of 0.42 log CFU/cm^2 after cleaning. Every other high-touch surface sampled in the bathroom decreased an average of 0.35 log CFU/cm^2 after cleaning.

Consistent with our findings from the guest traffic area and bed area, coliform

TABLE **1**

Results of *t*-Tests Comparing High-Touch Surfaces in the Guest Traffic Area

Surface	Aerobic Plate Count				Coliforms				*Staphylococcus aureus*				ATP Meter			
	M	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*
Bedroom doorknob before	0.61	0.41	0.13	-1.412	0.30	0.00	0.00	-0.100	0.80	0.59	0.19	2.232*	113	134	42	1.510
Bedroom doorknob after	0.91	0.72	0.23		0.40	0.32	0.10		0.37	0.22	0.07		49	25	8	
Closet handle before	1.02	1.17	0.37	-0.046	0.54	0.56	0.18	0.796	1.00	1.21	0.38	1.312	59	30	9	0.251
Closet handle after	1.04	0.98	0.31		0.40	0.32	0.10		0.50	0.42	0.13		55	37	12	
Drapery pull handle before	0.51	0.47	0.15	-0.891	0.47	0.54	0.17	0.524	0.51	0.34	0.11	1.964*	18	16	5	0.338
Drapery pull handle after	0.81	0.83	0.26		0.37	0.22	0.07		0.30	0.00	0.00		16	16	5	
Tabletop before	1.23	1.17	0.37	0.639	0.30	0.00	0.00	-1.796	1.27	1.05	0.33	2.206*	447	693	219	1.151
Tabletop after	0.92	0.81	0.26		0.64	0.60	0.19		0.64	0.55	0.17		216	477	151	
Table handle before	0.89	0.82	0.26	-0.284	0.30	0.00	0.00	-1.838	0.93	0.77	0.24	0.889	102	87	27	1.856*
Table handle after	1.01	0.82	0.26		0.65	0.60	0.19		0.61	0.52	0.16		59	36	12	
Dresser handle before	1.37	1.00	0.32	0.872	0.30	0.00	0.00	-1.479	1.29	1.09	0.35	1.587	56	36	11	0.966
Dresser handle after	0.95	0.78	0.25		0.63	0.71	0.22		0.76	0.64	0.20		42	39	12	
Climate control panel before	0.80	0.90	0.29	-0.668	0.30	0.00	0.00	-1.819	0.81	0.82	0.26	1.964*	59	34	11	2.209*
Climate control panel after	1.06	0.74	0.23		0.66	0.63	0.20		0.30	0.00	0.00		39	15	5	
Iron handle before	1.03	0.82	0.26	-0.172	0.30	0.00	0.00	-1.796	0.90	0.82	0.26	2.328*	19	21	7	0.664
Iron handle after	1.11	0.84	0.27		0.64	0.60	0.19		0.30	0.00	0.00		15	15	5	
Coffee maker before	1.84	1.09	0.34	1.353	0.51	0.34	0.11	-1.034	1.71	1.13	0.36	2.473*	72	90	28	1.283
Coffee maker after	1.29	0.87	0.28		0.76	0.64	0.20		0.93	0.60	0.19		36	19	6	
Door safety latch before	0.74	0.63	0.20	-0.444	0.30	0.00	0.00	-1.000	0.64	0.60	0.19	0.271	184	209	66	1.967*
Door safety latch after	0.90	0.85	0.27		0.48	0.57	0.18		0.57	0.46	0.15		63	41	13	
Door peephole before	0.73	0.57	0.18	-0.863	0.40	0.32	0.10	-1.281	0.65	0.60	0.19	0.285	26	14	4	1.363
Door peephole after	1.06	0.77	0.24		0.62	0.68	0.21		0.60	0.50	0.16		20	14	4	
Trash can rim before	1.40	1.14	0.36	-0.299	0.47	0.37	0.12	-0.532	1.34	1.06	0.33	0.023	25	16	5	1.049
Trash can rim after	1.54	0.78	0.25		0.61	0.66	0.21		1.33	0.69	0.22		18	13	4	
Carpet floor before	2.68	0.63	0.20	2.938**	0.30	0.00	0.00	-1.000	2.30	1.03	0.32	0.861	11	12	4	-0.509
Carpet floor after	2.01	1.01	0.32		0.47	0.54	0.17		1.95	1.05	0.33		12	16	5	
Bedroom light switch before	1.17	0.99	0.31	0.446	0.30	0.00	0.00	-1.441	0.94	1.01	0.32	0.179	95	55	18	1.853*
Bedroom light switch after	0.96	0.88	0.28		0.57	0.59	0.19		0.85	1.05	0.33		58	55	18	

* $p < .05$, ** $p < .01$, $n = 10$, $df = 9$.

Note. ATP = adenosine triphosphate.

counts detected before cleaning (M = 0.46, SD = 0.44) significantly increased after the room was cleaned (M = 0.81, SD = 0.14, $t(14)$ = -3.369, p = .002). High-touch surfaces that significantly increased in microbial counts following the bathroom cleaning include the amenity tray (M = -0.68, SD = 0.96, p = .026) located next to the bathroom sink that is used to store hand soap, lotion, and shampoo; sink faucet handles (M = -0.55, SD = 0.63, p = .011); doorknob inside bathroom (M = -0.58, SD = 0.90, p = .036); and hair dryer (M = -0.74, SD = 0.93, p = .016). Although coliform counts on most surfaces increased after cleaning, the shower floor was the only surface that had an average reduced log CFU/cm^2 and was found to be significantly cleaner after cleaning (M = 0.90, SD = 1.49, p = .044). All other surfaces

TABLE **2**

Results of *t*-Tests Comparing High-Touch Surfaces in the Bed Area

Surface	Aerobic Plate Count				Coliforms				*Staphylococcus aureus*				ATP Meter			
	M	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*
Bedside lamp switch before	1.97	0.49	0.15	3.179**	0.51	0.34	0.11	-0.980	1.67	0.80	0.25	1.552	81	64	20	0.872
Bedside lamp switch after	1.09	0.91	0.29		0.74	0.67	0.21		1.08	0.90	0.28		56	53	17	
Phone handset before	1.21	1.05	0.33	0.461	0.54	0.56	0.18	-1.036	1.04	0.88	0.28	0.718	84	111	35	1.413
Phone handset after	1.00	0.82	0.26		0.84	0.78	0.25		0.77	0.69	0.22		38	22	7	
Phone dial pad before	1.21	0.99	0.31	0.079	0.30	0.00	0.00	-1.881*	1.08	0.92	0.29	0.163	43	35	11	-0.508
Phone dial pad after	1.18	0.91	0.29		0.74	0.74	0.23		1.01	0.86	0.27		49	46	15	
TV remote control before	1.75	0.97	0.31	0.987	0.37	0.22	0.07	-2.641*	1.28	0.95	0.30	0.851	337	436	138	1.806
TV remote control after	1.35	0.93	0.29		0.91	0.68	0.21		0.97	0.71	0.22		125	140	44	
Bedside clock/phone dock before	2.19	0.81	0.26	2.118*	0.56	0.62	0.20	-0.687	1.92	1.02	0.32	2.483*	118	60	19	2.995**
Bedside clock/phone dock after	1.37	0.76	0.24		0.82	0.87	0.27		1.02	0.68	0.21		60	41	13	
Pillowcase before	1.79	0.73	0.23	2.231*	0.30	0.00	0.00	-1.321	1.71	0.84	0.26	3.243**	383	866	274	1.385
Pillowcase after	1.05	1.01	0.32		0.57	0.65	0.20		0.99	0.94	0.30		4	5	1	
Nightstand top before	2.21	1.30	0.41	1.83	0.51	0.66	0.21	-1.168	1.69	1.37	0.43	2.301*	160	89	28	0.867
Nightstand top after	1.31	0.91	0.29		0.93	0.75	0.24		0.82	0.73	0.23		131	68	21	
Nightstand handle before	1.05	1.10	0.35	-1.649	0.47	0.37	0.12	-1.464	1.06	1.08	0.34	1.707	67	67	21	0.043
Nightstand handle after	1.56	0.87	0.27		0.95	0.92	0.29		0.75	0.98	0.31		66	41	13	

* $p < .05$, ** $p < .01$, $n = 10$, $df = 9$.
Note. ATP = adenosine triphosphate.

sampled in this area increased an average of 0.37 log CFU/cm^2.

For *S. aureus*, microbial counts detected before cleaning (M = 1.61, SD = 0.60) significantly decreased after the bathroom was cleaned (M = 0.82, SD = 0.28, $t(14)$ = 6.187, p < .001). While all the high-touch surfaces decreased for this microorganism after the bathroom was cleaned, the surfaces that had significant decreases in the average log CFU/cm^2 were the toilet handle (M = 1.00, SD = 0.76, p = .001); toilet seat (M = 0.84, SD = 0.90, p = .008); sink faucet handles (M = 0.97, SD = 0.61, p < .001); bathroom floor (M = 1.13, SD = 1.12, p = .005); shower floor (M = 1.91, SD = 1.29, p < .001); toilet paper holder (M = 0.68, SD = 0.79, p = .011); bathroom light switch (M = 0.82, SD = 0.81, p = .006); doorknob inside bathroom (M = 1.05, SD = 0.68, p < .001); doorknob outside bathroom (M = 0.69, SD = 1.12, p = .042); and vanity surface (M = 1.37, SD = 0.76, p = .002). All the other surfaces decreased an average of 0.26 log CFU/cm^2.

Our analysis of the ATP meter data collected in the bathroom area indicates that the RLUs detected before cleaning (M = 158.88, SD = 175.47) significantly decreased after the room was cleaned (M = 51.23, SD = 24.90, $t(14)$ = 2.285, p = .019). The surfaces that had a significant decrease in RLU/cm^2 included the toilet handle (M = 45.50, SD = 69.50, p = .034); sink faucet handles (M = 122.30, SD = 63.75, p < .001); shower floor (M = 76.30, SD = 112.63, p = .030); toilet paper holder (M = 9.50, SD = 14.80, p = .037); light switch in the bathroom (M = 84.20, SD = 140.83, p = .046); and doorknob outside bathroom (M = 46.3, SD = 78.59, p = .048). Our results also indicate that the doorknob inside of the bathroom and the hair dryer increased in average RLUs detected after the bathroom was cleaned by 16 RLU/cm^2 and 20 RLU/cm^2, respectively. All other surfaces decreased an average of 163 RLU/cm^2 after the bathroom was cleaned. The results for the paired samples *t*-test in the bathroom area are shown in Table 3.

Discussion

Previous research has addressed public health concerns due to potential sources of community-associated infections resulting from microorganisms found in hotel environments (Jaradat et al., 2020; Xu, Mkrtchyan, et al., 2015; Xu, Weese, et al., 2015). Specifically, high-touch surfaces found in hotel rooms could serve as fomites that can transmit potentially pathogenic microorganisms through either direct contact (e.g., surface-to-mouth) or indirect contact (e.g., surface-to-hand-to-eye, surface-to-hand-to-mouth) (Lopez et al., 2013). Although microbiological testing of hotel rooms might not be practical for day-to-day operations, the findings from our study show that the number of environmental and potentially pathogenic

TABLE **3**

Results of *t*-Tests Comparing High-Touch Surfaces in the Bathroom Area

Surface	Aerobic Plate Count				Coliforms				*Staphylococcus aureus*				ATP Meter			
	M	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*	*M*	*SD*	*SEM*	*t*
Toilet handle before	1.72	0.90	0.29	1.622	0.30	0.00	0.00	-1.769	1.76	0.71	0.22	4.176***	76	83	26	2.070*
Toilet handle after	1.13	0.81	0.26		0.79	0.88	0.28		0.76	0.62	0.20		31	35	11	
Toilet seat before	1.57	1.14	0.36	1.429	0.30	0.00	0.00	-1.000	1.48	1.18	0.37	2.937**	292	684	216	1.148
Toilet seat after	0.92	0.85	0.27		0.50	0.63	0.20		0.64	0.58	0.18		42	30	10	
Amenity tray before	1.67	1.08	0.34	0.453	0.37	0.22	0.07	-2.234*	1.51	1.15	0.36	0.447	76	80	25	0.851
Amenity tray after	1.53	1.03	0.33		1.05	0.87	0.27		1.24	1.53	0.48		48	65	21	
Bathroom sink before	2.19	1.24	0.39	1.321	0.40	0.32	0.10	-1.321	1.64	1.20	0.38	1.200	166	317	100	1.198
Bathroom sink after	1.68	0.81	0.26		0.67	0.78	0.25		1.13	0.66	0.21		43	49	15	
Sink faucet handles before	2.16	0.99	0.31	2.083*	0.37	0.22	0.07	-2.748*	1.86	1.15	0.36	5.019***	154	83	26	4.608***
Sink faucet handles after	1.29	1.04	0.33		0.92	0.74	0.23		0.89	0.90	0.28		61	43	14	
Bathroom floor before	2.42	1.14	0.36	2.105*	0.55	0.79	0.25	-1.719	2.07	1.38	0.44	3.223**	122	115	36	1.030
Bathroom floor after	1.36	1.10	0.35		1.00	0.95	0.30		0.94	0.82	0.26		73	84	27	
Shower floor before	3.74	1.03	0.32	5.362***	1.86	1.46	0.46	1.908*	3.17	1.08	0.34	4.690***	122	120	38	2.142*
Shower floor after	2.26	0.52	0.16		0.96	0.77	0.24		1.26	0.88	0.28		46	38	12	
Toilet paper holder before	1.68	1.03	0.33	0.868	0.44	0.30	0.09	-1.369	1.49	0.81	0.25	2.762*	22	16	5	2.029*
Toilet paper holder after	1.26	0.87	0.27		0.83	0.96	0.30		0.81	0.73	0.23		13	12	4	
Bathroom light switch before	1.12	0.81	0.26	0.086	0.30	0.00	0.00	-1.475	1.45	0.80	0.25	3.188**	179	167	53	1.891*
Bathroom light switch after	1.08	0.93	0.29		0.66	0.77	0.24		0.63	0.57	0.18		94	70	22	
Doorknob inside bathroom before	1.67	0.90	0.28	1.252	0.30	0.00	0.00	-2.034*	1.73	0.97	0.31	4.881***	60	50	16	-0.407
Doorknob inside bathroom after	1.23	0.80	0.25		0.88	0.90	0.29		0.68	0.52	0.16		75	118	37	
Doorknob outside bathroom before	1.57	0.90	0.29	0.254	0.30	0.00	0.00	-1.494	1.13	0.90	0.28	1.947*	105	68	21	1.863*
Doorknob outside bathroom after	1.48	0.76	0.24		0.69	0.83	0.26		0.44	0.44	0.14		58	52	17	
Toilet bowl before	1.55	0.76	0.24	1.237	0.50	0.63	0.20	-1.207	0.92	0.73	0.23	0.916	735	2234	706	1.026
Toilet bowl after	1.10	0.82	0.26		0.93	0.77	0.24		0.75	0.65	0.21		16	18	6	
Hair dryer before	1.45	0.77	0.24	-1.321	0.30	0.00	0.00	-2.519*	0.99	0.68	0.22	0.211	51	31	10	-1.580
Hair dryer after	1.87	0.66	0.21		1.04	0.93	0.29		0.93	0.72	0.23		71	52	17	
Vanity surface before	2.61	0.79	0.30	4.420**	0.30	0.00	0.00	-1.333	2.19	1.12	0.42	4.796**	200	350	124	0.956
Vanity surface after	1.36	0.69	0.26		0.70	0.79	0.30		0.81	0.51	0.19		76	47	16	
Shower handle before	0.97	0.85	0.32	0.359	0.30	0.00	0.00	-1.000	0.71	0.72	0.27	1.002	21	21	7	0.334
Shower handle after	0.77	0.85	0.32		0.60	0.79	0.30		0.40	0.26	0.10		16	31	11	

*$p < .05$, **$p < .01$, ***$p < .001$, $n = 10$, $df = 9$.
Note. ATP = adenosine triphosphate.

microorganisms increased on many high-touch surfaces after the room was cleaned. The results from our environmental sampling identified recurring patterns throughout three areas in the rooms sampled (n = 10), as well as some inconsistencies based on the microorganism detected and the sampling method (i.e., microbial counts versus ATP meter measurements).

Guest Traffic Area

Based on our results, high-touch surfaces that had the highest level of contamination in the guest traffic area were the tabletops, coffee makers, trash can rims, and carpet floors at the entry point of the room, specifically for APCs and *S. aureus* microbial counts. Of these surfaces, the entry carpet had the highest log concentrations in the guest traffic area for both APCs and *S. aureus* microbial counts; notably, this surface had some of the lowest RLU readings according to the ATP meter data we collected. In terms of the data collected from the ATP meter, the tabletop had the highest average RLU/cm^2 of all surfaces in the guest traffic area and the second-highest RLUs of all surfaces sampled in our study, with the toilet bowl having the highest average RLU/cm^2.

In contrast, the surfaces with the lowest level of microbial contamination and organic residue detected by the ATP meter in the guest traffic area included the bedroom doorknob, drapery pull handle, climate control panel, door safety latch, and bedroom light switch. All of these surfaces are consistent with messaging from leading hotel brands that lists the high-touch surfaces they have focused enhanced cleaning efforts on (Hilton, 2021; IHG, 2021; Marriott, 2021; Wyndham Hotels, 2021).

Our findings suggest that although some high-touch surfaces in guest rooms receive adequate attention in terms of cleaning, lodging operations need to focus on other high-touch surfaces found in hotel rooms that can serve as a reservoir for microbial contamination, namely the room carpeting. Although our analysis showed that the carpet was deemed to be cleaner after the room was cleaned, there were visible stains at the entry point of the rooms and an approximate average of 2 log CFU/cm^2 for APCs and *S. aureus* microbial counts—a finding that was significantly higher than any other high-touch surface found in the guest traffic area after the room was cleaned.

Loo and Leung (2018) identified hotel room carpets as highly influential to guest satisfaction in that carpets serve as indicators of the physical environment's cleanliness and speak to the perceived service quality of the hotel in terms of cleaning processes. As such, room carpets that are poorly maintained, have visible signs of filth, or emit unpleasant odors can have a negative effect on the perceived value (i.e., the money spent on the daily room rate) and overall satisfaction with the property by the guest.

Moreover, research in clinical settings has examined the microbiological risks associated with inadequately cleaned carpeting in patient rooms. In a study examining hospital floors as a potential vehicle for pathogen transmission, Deshpande et al. (2020) found that patient rooms frequently were contaminated with healthcare-associated pathogens, specifically *Clostridium difficile*, methicillin-resistant *S. aureus* (MRSA), and vancomycin-resistant enterococci—and that these pathogens were easily transferred from the floor to patients' hands via contact with other fomites (e.g., cell phones, pillows, clothing) that have made contact with the floor. Further, Anderson et al. (2011) found that higher microbial counts were detected on carpeted flooring than on tiled flooring and that many of the microorganisms detected on hospital room carpets (e.g., *E. coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *S. aureus*) were present on the patients during their hospital stays.

These findings are relevant to our study because, as carpet is a porous surface and difficult to clean, the microorganisms on floors can easily be transferred to guests and other high-touch surfaces in the guest room via contact with contaminated surfaces. In one instance while collecting samples after a room was clean, it was observed that a trash can had been placed on top of the table in the guest room, most likely to change the trash bag or to clean the carpet beneath the trash can. In either case, this observation serves as a prime example of how surfaces can be recontaminated through contact with other fomites in the room. Moreover, Zemke et al. (2015) performed an exploratory study to determine guest perceptions of hotel room cleanliness and found that the hotel room carpet was among the surfaces in the room that frequent travelers perceived a significantly higher risk of acquiring an illness from. Therefore, the authors suggested that housekeeping practices and trainings consider the impact of the guest room carpet as a potential fomite and the importance of reducing cross-contamination.

Bedroom Area

According to our results, nightstands and bedside clocks/phone docks had the highest levels of contamination before cleaning, followed by bedside lamp switches, pillowcases, and TV remote controls, respectively. After these surfaces were cleaned, they still maintained an average log CFU/cm^2 above 1.0 for APCs and an approximate average of 1.0 log CFU/cm^2, except for the nightstand handle. Additionally, all high-touch surfaces in this area increased in average coliform counts, with the TV remote control, nightstand top, and nightstand handle approaching 1.0 log CFU/cm^2 after cleaning. ATP meter results demonstrate similar findings in terms of the surfaces with the greatest amount of organic matter detected; however, they do not account for the increase in coliform counts after the room was cleaned.

As all of these surfaces were located on the nightstand next to the bed, we suggest that surfaces near the guest need to receive additional attention from housekeeping staff during cleaning, as guests are more likely to interact with these surfaces during their time in the room. Further, trace amounts of food were observed on the nightstand, which could serve as an extrinsic factor that either provides protection from disinfectants through biofilm formation (Kuda, Iwase, et al., 2011; Kuda, Shibata, et al., 2015) or a source of nutrients that allow microorganisms to persist on these surfaces (Sun, 2011).

In a study that examined the frequency of contact with high-touch and mutual-touch surfaces in patient rooms, Cheng et al. (2015) found that bed rails and bedside tables were the most-touched surfaces in patient rooms by healthcare workers, patients, and visitors. Moreover, research in the clinical setting has found that these and other surfaces near patient beds were commonly contaminated with MRSA and that environmental disinfection efforts that have focused on areas near patient beds have shown a significant decrease in MRSA infections (Dancer et al., 2014). Further, Phan et al. (2019) found that the most-touched environmental surfaces in the patient room were the tray table, bed surfaces, and medical equipment located near the patient bed area. The authors suggested that because these surfaces have been implicated in viral and bacterial contamination, transmission of microorganisms via contact with these fomites is likely to occur.

Bathroom Area

It is not surprising that the bathroom area had the most significant decreases in microbial counts and RLU readings, considering that bathrooms are among the key areas in guest satisfaction ratings for lodging properties (Prasad et al., 2014). Furthermore, bathroom cleaning is an inherent part of standard operating procedures in the lodging industry (Casado, 2012). A survey to determine consumer perceptions of hotel room cleanliness by Zemke et al. (2015) supports the idea that lodging properties focus more on cleaning the bathroom area in guest rooms because consumers generally think that bathroom surfaces are the cleanest; these findings suggest that bathroom surfaces are generally easier for guests to observe as a marker of overall room cleanliness.

Further, many of the high-touch surfaces—as identified by leading hotel brands (Hilton, 2021; IHG, 2021; Marriott, 2021; Wyndham Hotels, 2021), sanitation companies (Ecolab, 2021; Reckitt, 2021), and health organizations (CDC, 2024a; WHO, 2021)—were located in the bathroom area.

Although many of the surfaces in the bathroom area after cleaning showed a decrease in RLU readings and log CFU/cm^2, it is important to note that research looking at collected environmental samples in hotel guest rooms has identified the highest level of surface contamination to be found in the bathroom. Consistent with our findings, Almanza et al. (2015) found that the surfaces with the highest levels of APCs included samples collected from the toilet bowl, bathroom floor, and bathroom sink—and that the bathroom sink was among the surfaces with the highest coliform counts. Additionally, the shower floor maintained a relatively high log CFU/cm^2 throughout the duration of their study.

Practical Implications for Practitioners

Most research conducted in the hospitality setting has focused on evaluating visible surface cleanliness by using an ATP meter. Few studies, however, have focused on assessing microbial counts of high-touch surfaces found in hotel guest rooms. Park et al. (2019) propose that 1) the concept of high- and low-touch surfaces originates from research done in the hospital and healthcare industry and 2) there is limited information regarding contamination of high-touch areas for the lodging industry. Thus, studies conducted in clinical settings that focus on high-touch fomites found in patient rooms can provide hospitality-focused research with new insights regarding the presence, persistence, and transfer of microorganisms from surface-to-surface and surface-to-guest via high-touch fomites found in hotel rooms.

For example, the methods in our study were adopted from the CDC (2019) *Guidelines for Environmental Infection Control in Health-Care Facilities* and tailored for the environment of a standard hotel guest room. The principles highlighted in these guidelines serve as a framework to conduct similar research by identifying suitable sampling surfaces, assay techniques, and procedures. Further, these guidelines provide a justification for our study by determining when such a study is appropriate (i.e., changes in infection control practices), including the enhancement of cleaning procedures in response to a pandemic.

Although it might not be practical to use microbiologic techniques in day-to-day operations, research using environmental sampling techniques has addressed the importance of having a microbiologic comparator when assessing changes in infection control practices (Snyder et al., 2013). This concept is not foreign in the hospitality context: environmental public health professionals already use data from research on microbial contamination and microbial prevention methods to implement strategies targeted at reducing risks to public health. Examples include food safety management systems in food service operations (Food and Drug Administration [FDA], 2023), conducting hazard analyses and identifying critical control points for various contaminants that enter hospitality operations (Altemimi et al., 2022; Soriano et al., 2002), and creating guidelines to minimize microbial safety hazards for fresh fruits and vegetables (FDA, 2018).

As such, our study provides a more robust list of high-touch surfaces that can be adopted by the lodging industry to enhance preexisting cleaning procedures. Although properties might not all have the same high-touch surfaces, our list (Tables 1, 2, 3) can be tailored easily to address property-specific needs.

In terms of high-touch surfaces, our study incorporated elements of triangulation (a method commonly used in qualitative studies) to identify high-touch surfaces across leading brands, sanitation companies, and public health agencies to create a list of high-touch surfaces identified across these agencies. Additionally, combining publicly available information from leading hotel brands allowed us to account for variation in cleaning products, which in turn informed our methods by allowing us to identify the active ingredient in each cleaner to determine the appropriate times between sampling events and the incorporation of a neutralizing agent in the sample collection tubes used after cleaning.

The interdisciplinary nature of our study methods offers meaningful contributions to scientific literature and industry practice by integrating hard science and social science to address an understudied research area and respond to calls to examine the evolving relationship between hospitality and healthcare sectors (Jiang & Wen, 2020).

Additionally, our analysis identified high-touch surfaces that could benefit from greater attention from housekeeping staff to reduce the microbial contamination and organic matter present on these surfaces. This study finding is meaningful for hotel and lodging operators in terms of inspections conducted through the Diamond Inspection Program from AAA. For more than 80 years, AAA (2021) has awarded lodging properties various Diamond Ratings based on inspections that evaluate the quality of employee satisfaction and safety, guest experience, amenities, and service delivery. In response to the COVID-19 pandemic, AAA incorporated an Inspected Clean Program in July 2021 into their Diamond Rating criteria that incorporates the use of an ATP meter to evaluate the cleanliness of eight randomly selected high-touch surfaces found in hotel room guest traffic areas and bathrooms. These surfaces are the ones that we sampled in our study.

Interestingly, a study conducted by Xu, Mkrtchyan, et al. (2015) to establish a baseline assessment of sanitary status in hotel rooms found that the average ATP readings for designated surfaces did not differ among hotel classes and that these findings could be attributed to similar cleaning patterns throughout hotel classes. Considering these findings, adopting and tailoring the high-touch surface list in our study could be beneficial for the lodging industry to better prepare for future inspections and future public health events.

Limitations

As with other research, our study is not without limitations. Our study was conducted at only one midscale hotel property in the Southern U.S. that had implemented ECPs in response to the COVID-19 pandemic. Although our study was exploratory in nature and used robust data collection methods and analyses, future research could benefit from using the methods presented here to examine multiple properties across different brands to better inform the lodging industry and environmental health inspectors.

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